

INSTRUCTIONS AND APPLICATIONS

Deviation Bridge Type 1506



An instrument designed for production control of ceramic capacitors and small inductances, as well as for A.C. bridge measurements in laboratories.

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Deviation Bridge

Type 1506

Reprint: March 1961

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Description.

General.

The Deviation Bridge is a measuring bridge for testing resistors, capacitors and inductors.

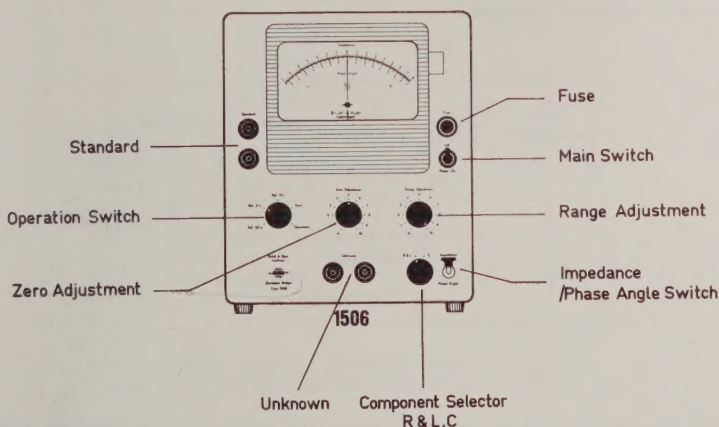


Fig. 1. Drawing of the Deviation Bridge Type 1506.

It consists of a Wheatstone Bridge with two fixed resistors and four input terminals for connection of an external standard and the unknown component. The bridge is operated from a built-in generator. The diagonal voltage is, via a two-stage amplifier, fed to a phase-sensitive demodulator, the output voltage of which is measured on a moving coil instrument with big, interchangeable scales. The scale-reading is the positive and negative deviation in per cent and the positive and negative phase angle in radians between the standard and the unknown component.

Three calibrated, and three blank scales for special calibration purposes are supplied with the Bridge.

Oscillator and Bridge Section.

The oscillator, which is of the Hartley type, operates at a frequency of 100 kc/s. The output voltage is fed to an output amplifier via a resistor or a R-C network. The selection is made by means of the switch marked "Impedance", "Phase Angle". When switched in, the R-C network introduces a 90° phase shift of the output signal.

Via a potentiometer marked "Range Adjustment" the signal is fed to the output amplifier consisting of a pentode. In order to avoid any phase shift in being produced in this stage, the load must be true resistive. By parallelling the output transformer with a capacitor and making the transformer tuneable by introducing an adjustable air-space in the iron core, the anode circuit may be adjusted to the bridge frequency, whereby the said condition is obtained. This is only true when the secondary load of the transformer is resistive. By a capacitive load (i.e. when measurements are carried out on capacitors) the small extra phase shift causes an error which is corrected for by the table given on page 00. To stabilize the output amplifier this is, furthermore, supplied with negative feedback.

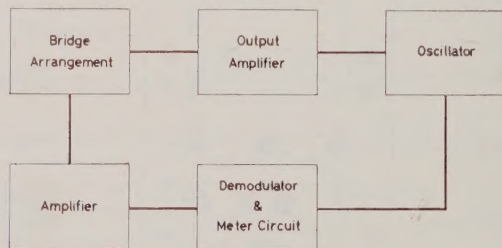


Fig. 2. Block diagram of Type 1506.

The two fixed resistors incorporated in the Wheatstone Bridge are wire-wound resistors of $100\ \Omega$, the mutual point of which is grounded. The two other arms of the bridge are fed to two pairs of terminals marked "Standard" and "Unknown". None of the apparatus terminals is connected to chassis. The upper of the left terminals and the right terminal at the bottom are connected to chassis through resistances of about $100\ \Omega$, having an AC potential of maximum 2 volts with respect to chassis. The other two terminals, marked in white, are mutually connected and led to the input circuit of the amplifier. The bridge arrangement involves, furthermore, a switch marked "R & L", "C", the purpose of which is to interchange the standard and the unknown component. This is to permit direct reading in % deviation of capacity (and not of impedance), and is necessary because the impedance of a capacitor is inversely proportional to the capacity.

Amplifier and Demodulator Section.

Whenever a difference in magnitude or phase angle is present between the standard and the unknown component, a diagonal voltage occurs in the bridge arrangement. This voltage is fed directly to the input of a two stage resistance coupled amplifier, which is supplied with negative feedback to obtain a stable operation and a high input impedance. (When measuring too high impedance values, the input impedance of the amplifier will load the bridge, and consequently cause erroneous measurements. See correction curves on p. 19). The output of the amplifier is connected to a demodulation circuit which makes the instrument insensitive to hum and noise voltages to a certain degree, because the demodulator preferably responds to signals of the same frequency as that of the oscillator. Furthermore, positive and negative deflections are obtained for positive or negative deviations from the standard, respectively.

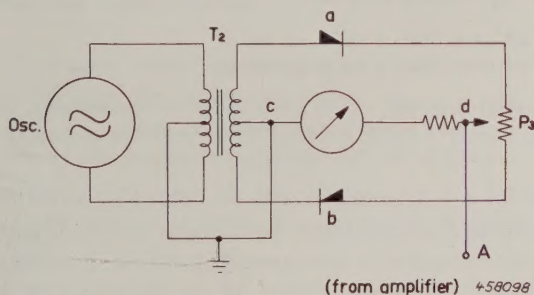


Fig. 3. Principle diagram of the demodulator circuit.

In fig. 3 is shown a basic diagram of the demodulator circuit. It can be seen from the figure that a part of the oscillator voltage is rectified by means of the rectifier cells a and b, and that by adjusting P_3 (marked "Zero Adjustment") a position of the movable arm of the potentiometer can be found, for which no current will flow through the meter, when no signal is fed to A. Whenever a diagonal voltage occurs in the bridge arrangement, the corresponding amplified signal, with no additional phase shift, is present at A.

If this voltage is in phase with the voltage E_T across the secondary of the transformer T_2 as indicated in figure 4 and the rectifier cells a and b are open, only a small current will pass through the meter due to the shunting effect of the rectifiers.

When the cells are blocked the current will flow from c to d, having a magnitude which is much greater than when the cells are open. A DC component of the output voltage from the amplifier will thus be present across the meter, causing this to deflect.

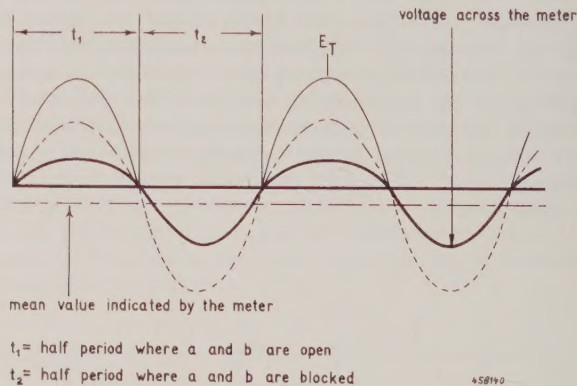


Fig. 4. Operating principle of the phase sensitive demodulator, Oscillator and bridge output voltage in phase.

If the voltage at A is in antiphase with the voltage E_T across T_2 the sign of the DC component developed across the meter is reversed. This can be seen from fig. 5.

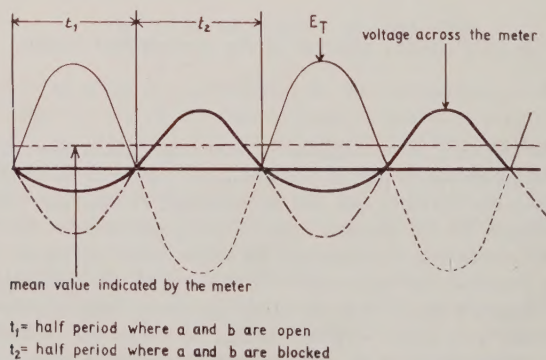


Fig. 5. Operating principle of the phase sensitive demodulator, Oscillator and bridge output voltage in anti-phase.

With the output voltage from the amplifier 90° out of phase, relative to the voltage E_T , the voltage developed across the meter will be as indicated in fig. 6. No DC component is then present, and the deflection on the meter will be zero.

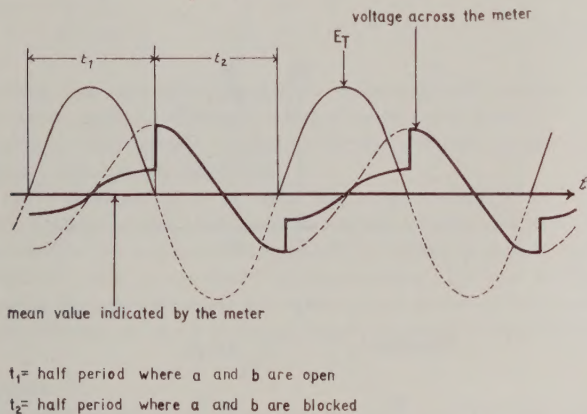


Fig. 6. Operating principle of the phase sensitive demodulator. Oscillator and bridge output voltage 90° out of phase.

Consequently only the in-phase (or in-antiphase) component of the voltage will be indicated by the meter. By measuring both components, the magnitude as well as the phase angle of the diagonal voltage are determined. With the switch marked "Impedance", "Phase Angle" in position "Impedance", the in phase (or in-antiphase) component is measured, and with the switch in position "Phase Angle" the 90° out of phase component is indicated. In fig. 7 a vector diagram of the voltages appearing in the Wheatstone Bridge arrangement during measurements is shown.

The vectors AB and BC represent the voltages across the two fixed resistors, respectively, the vectors AD and DC the voltages across the "standard" and the "unknown" impedances, respectively, and the vector BD the voltage applied to the amplifier.

When impedance measurements are taken only the voltage represented by the vector BD_1 is indicated by the meter.

For phase-angle measurements the meter indication will be proportional to the voltage BD_2 .

It is seen from the diagram that the point D might move along a line drawn through the points D— D_1 without influencing the magnitude of the vector BD_1 .

Analogously the magnitude of the vector BD_2 will not be influenced if the point D moves along a line drawn through the points $D - D_2$.

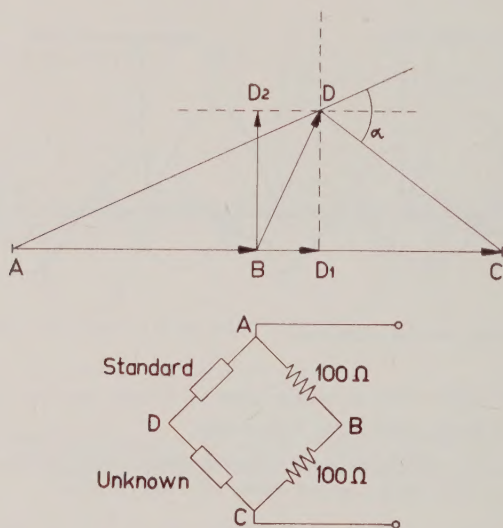


Fig. 7. Vector diagram of bridge voltages.

As the difference in phase angle between the "standard" and the "unknown" is α (see fig. 7) this means that:

1. When the phase angle of the "unknown" is very much different from the phase angle of the "standard" the measurement of impedance deviation is inaccurate.
2. When the impedance of the "unknown" is very much different from the impedance of the "standard" the measurement of phase angle deviation will be inaccurate.

The maximum inaccuracy will be present when both phase angle and impedance measurements show maximum deviation between "standard" and "unknown".

Meter Section.

As previously mentioned, different dials can be inserted in the large square type indicating meter.

The three calibrated scales, supplied with the instrument cover the following ranges of deviation measurements:

<i>Impedance Deviation</i>	<i>Phase Angle Deviation($\tan \delta$)</i>	<i>Range Adjustment</i>
— 1.5 % to + 1.6 %	— 1.5 to + 1.5×10^{-2}	1 %
— 7 % to + 8 %	— 7 to + 7×10^{-2}	5 %
— 25 % to + 35 %	— 30 to + 30×10^{-2}	20 %

The moving coil instrument is slightly under-critically damped to secure maximum speed, and is perfectly protected against overload.

To be able to calibrate the apparatus for the different ranges in a quick way reference voltages are provided.

When the 1 % range is to be used the range switch is set to position "Ref. 1 %". By turning the knob marked "Range Adjustment" until the meter pointer deflects to the red mark on the scale, a voltage is applied to the input of the amplifier, with a magnitude corresponding to the one obtained when the impedance deviation between the standard and unknown impedance is 1 %.

Reference voltages for the 5 % and the 20 % ranges are also available.

Power Supply.

The European model is intended for use with 115, 127, 150, 220 or 240 volts AC, 40—400 c/s. Switching to the different line voltages is made by means of a screwdriver through a hole in the back plate. A pilot disc indicates the line voltage to be connected. The American model is designed for 115 volts, 60 c/s. The power consumption for both models is about 40 watts. The plate voltage to the oscillator is stabilized by a neon tube. A variation of 10 % in the power supply voltage will influence the meter deflection by less than 3 %, the zero point being independent of the line voltage.

Operation.

General Remarks.

During measurements it is advantageous to ground the apparatus.

The standard and the objects to be measured should be placed together with the bridge on a grounded metal plate.

If the object to be tested is grounded, the grounded pole should be connected to the right "Unknown" terminal, and the grounding of the cabinet be omitted. The capacity of the apparatus to ground is then connected across one of the built-in ratio resistors and should consequently be kept as low as possible.

When high impedances are being measured (large resistors and inductances, and small capacitors, respectively) the connections to the bridge should be taken into account.

Furthermore, no extra capacity must be introduced between chassis and the two terminals marked in white.

Operation Procedure.

1. Make sure that the Deviation Bridge is adjusted to the correct mains voltage. If not turn the pilot disc marked "Volt AC" on the rear panel of the instrument to the desired voltage (115 — 127 — 150 — 220 or 240 volt).
2. Connect the power cable to the mains and place the toggle switch marked "Power" in position "On". The light on the meter comes on immediately.
3. Allow a few minutes warm-up time.
4. Set the switch marked "Impedance"/"Phase Angle" in position "Impedance".
5. Place the meter scale corresponding to the desired measuring range (1 %, 5 %, 20 %) in the meter frame. (The scale is removed from the frame by pulling to the right).
6. Turn the operation switch (knob to the left) to "Zero". By means of the knob marked "Zero Adjustment" the meter pointer is set to 0.
7. Connect the standard component to the terminals marked "Standard" and the component to be checked to the terminals "Unknown".
8. Set the operation switch to the desired Ref. value ("Ref. 1 %", "Ref. 5 %" or "Ref. 20 %"). Turn the knob marked "Range Adjustment" until the meter pointer is on the red mark on the scale.

Note:

When measuring high impedances, the values obtained from the adjustment curves, shown on p. 19, should be used for the range adjustments, instead of the red mark on the scale.

9. Turn the "Component Selector" to the correct position (for resistors and inductances in position "R & L" and for capacitors in position "C"). For the influence of capacitive loading see table 1 on page 11.

10. Turn the operation switch to position "Operation" and the instrument is ready for use.
11. For *phase angle measurements* set the switch marked "Impedance", "Phase Angle" in position "Phase Angle". It is locked in this position by pushing it downwards and to the left.

Note:

To avoid overloading of the amplifier a check should be made that the meter deflection is kept within full scale deflection both with the press button switch in position "Impedance", and in position "Phase Angle".

12. The components to be tested are now successively connected to the two terminals marked "Unknown" and the meter deflection will give the deviation from the Standard directly in %.

Deflection to the right means positive deviation (unknown bigger than Standard), and deflection to the left negative deviation (unknown smaller than Standard).

	Range	Introduced Error	Capacity to be Tested
20 ‰	Impedance measurement	$0.01 \times b$	up to 50 nF
		$0.05 \times b$	100 nF
	Phase angle measurement	$0.01 \times a$	up to 50 nF
		$0.1 \times a$	100 nF
5 ‰	Impedance measurement	$0.01 \times b$	up to 50 nF
		$0.13 \times b$	100 nF
	Phase angle measurement	$0.01 \times a$	up to 50 nF
		$0.12 \times a$	100 nF
1 ‰	Impedance measurement	$0.02 \times b$	up to 30 nF
		$0.04 \times b$	50 nF
		$0.18 \times b$	100 nF
	Phase angle measurement	$0.02 \times a$	up to 30 nF
		$0.03 \times a$	50 nF
		$0.14 \times a$	100 nF

Table 1. The extra inaccuracy which is introduced when measurements are carried out on capacitors. With an impedance deviation reading of a % and a phase angle deviation reading of b % the inaccuracy on the 3 different % ranges are directly found.

Accessories.

Test Jig Type 3902.

The Test Jig Type 3902 is a design to be used in connection with the Deviation Bridge for rapid production control of resistors, capacitors, and inductances. It consists of a wooden board on which the Deviation Bridge should be placed. On the board in front of the instrument are placed two

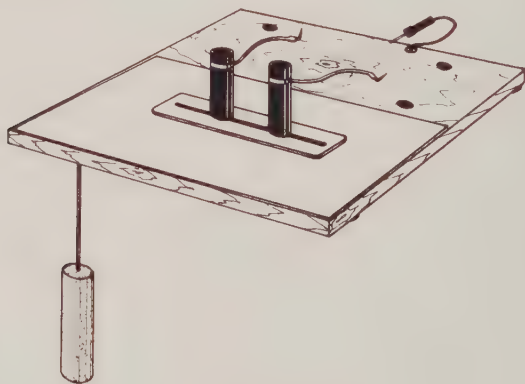


Fig. 8. Drawing of the Test Jig Type 3902.

posts designed with spring loaded contacts. The opening of the contacts is controlled by means of a lever, and the contacts can be directly connected to the terminals marked "Unknown". The lever is intended to be operated by means of the operators left knee. That part of the wooden board which is in front of the instrument is, furthermore, supplied with a steel plate. This may be connected to the instrument cover or to ground. The distance between the posts is adjustable to any spacing between 0 and 14 cm ($5\frac{1}{2}$ inch.). The measurements are carried out by engaging the lever for operating the contacts, placing the component to be measured between the two posts, and releasing the lever. The instrument then immediately shows the deviation from the standard-component employed.

Applications.

Measurements of Resistors and Capacitors in Laboratories.

In laboratories where resistors and capacitors are frequently measured, it might be practical to use a couple of measuring bridges of the type 1506, permanently connected to a resistor and a capacitor standard, as indicated in fig 9.

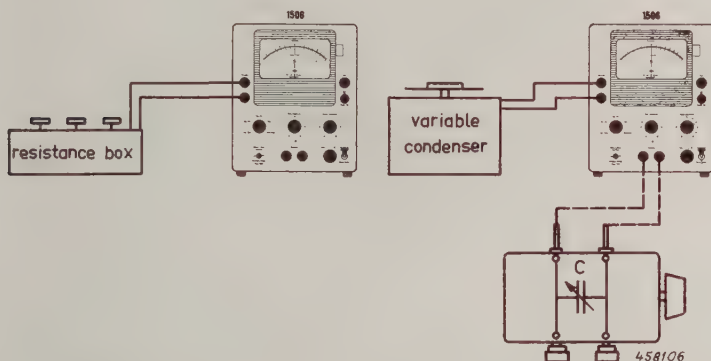


Fig. 9. Resistance box and variable capacitor connected to Deviation Bridge type 1506 for laboratory measurements.

Resistors are then measured on 1506 in the following way: The "Unknown" is connected to the Bridge, and the standard resistor is varied until the bridge is balanced. The unknown resistance can then be found immediately by reading the value indicated by the standard. This method of measurement is much quicker in practice than adjusting a Wheatstone Bridge, because the meter of 1506 responds much quicker than the usual light-spot galvanometer.

By employing a standard resistor, which is absolutely non-reactive, the reactive component of the unknown resistor can be determined by a phase-angle measurement. This might be a great advantage for many laboratory measurements. Due to the high measuring frequency the Bridge is not suitable for production control of resistors, because a too big phase angle deviation between the "Standard" and the "Unknown" may cause inaccurate measurements.

Capacitors may be measured on 1506 in the same way as resistors. In order to compensate for the connections to the variable capacitor and its minimum capacity, the unknown capacitor should be connected via a small extra measuring box, containing a balancing capacity. In this way, a quick and very exact measurement of small capacitors can be carried out.

Checking of Coils for Short-Circuit Turns.

A set-up as shown in fig. 10 might be useful for detection of short-circuits in the winding of i. f.-transformers, radio frequency coils or other inductances.

Two identical, measuring coils, a and b, equipped with relatively long iron cores, are balanced in the bridge arrangement. The inductance to be tested is then placed as shown in the figure.

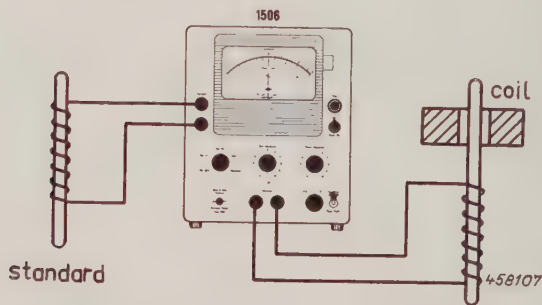


Fig. 10. Checking of coils for short-circuit turns.

If a short-circuit exists in the winding this will cause a decrease in the inductance of the coil b, whereby the balance of the bridge is disturbed.

In most cases the highest sensitivity is obtained by a phase angle measurement.

Checking of Litz-Wound R. F.-Coils for Broken Wires.

By employing the 1 % range of the Bridge it is possible to check litz-wound R. F.-coils for broken wires. A standard coil is then connected to the "Standard" terminals of the Bridge, whence the coil to be tested should be connected to the "Unknown" terminals.

The Bridge should be switched to phase angle measurements, and a deflection of the meter is observed if one of the litz-wires is broken or makes insufficient contact (bad soldering).

A deflection of approx. 1 % has been observed when one of the litz-wires was broken in a 20-cored litz.

Balance of Ganged Variable Capacitors.

For adjustment of mechanically coupled, variable capacitors the set-up shown in fig. 11 will be practical. The two stators are connected respectively to the upper left, and lower right terminal of the bridge, while the rotors, which are usually interconnected, are connected to one of the two remaining terminals. The balance, expressed in % deviation, may then be checked for all positions of the rotor.

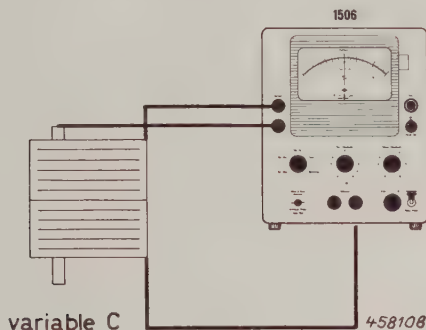


Fig. 11. Matching of ganged capacitors.

Direct-Reading Measurements of Capacitors.

The Devaition Bridge type 1506 may be used as a direct-reading instrument for measurements on capacitors. Two equal capacitors of exactly known value are connected across the "Standard" and "Unknown" terminals, as shown in fig. 12.

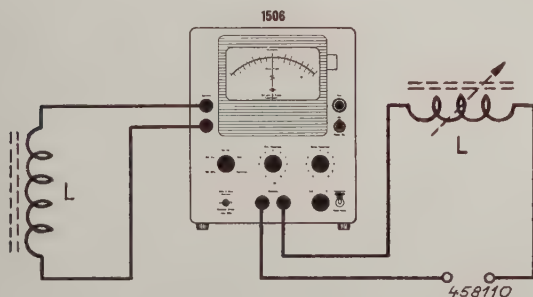


Fig. 12. Direct reading measurements of capacity values.

The capacitor to be measured is now connected in parallel with one of the "Standard" capacitors, and its value found as per cent increase of the fixed "Standard".

By choosing the "Standard" capacitors in such a way that the one connected to the "Standard" terminals consists of a fixed capacitor plus a small variable capacitor the adjustment procedure might be simplified.

A further simplification of the reading is obtained if the "Standard" capacitors are chosen as pure powers of 10.

The operation procedure is then as follows: Set zero, and adjust to reference. Then switch to "Operation" and bring the pointer to zero by means of the adjustable part of the "Standard" capacitance. When the fixed capacitors are very small the reference adjustment should be carried out in accordance with the adjustment curves on p. 19. The following table shows the measuring ranges and reference adjustments for various fixed standards, chosen as powers of 10.

Fixed Capacitors	Direct Reading Range	Adjustment to Reference %
$2 \times 100 \text{ pF}$	0— 1.5 pF	1.11
	0— 8 "	5.55
	0— 35 "	22.0
$2 \times 1000 \text{ pF}$	0— 15 "	1
	0— 80 "	5
	0— 350 "	20
$2 \times 0.01 \text{ } \mu\text{F}$	0— 150 "	1
	0— 800 "	5
	0— 3500 "	20
$2 \times 0.1 \text{ } \mu\text{F}$	0— 1500 "	1
	0— 8000 "	5
	0— 35000 "	20

Direct-Reading Measurements of Inductances.

In a similar way as for capacitors, it is possible to use the Deviation Bridge as a direct-reading meter for inductances. As shown in fig. 13, two fixed inductances are used, the inductance under test being connected in series with one of the fixed inductances.

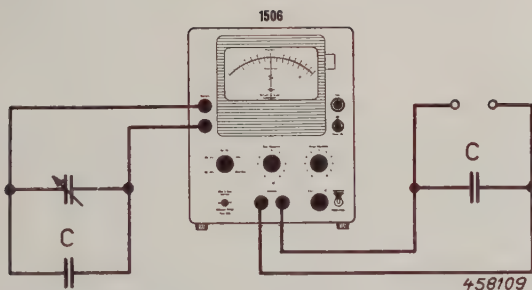


Fig. 13. Direct reading measurements of inductance values.

Fixed Inductances	Direct Reading Range	Adjustment to Reference %
$2 \times 20 \mu\text{H}$	0— 0.3 μH	1
	0— 1.6 „	5
	0— 7 „	20
$2 \times 100 \mu\text{H}$	0— 1.5 μH	1
	0— 8 „	5
	0— 35 „	20
$2 \times 1 \text{ mH}$	0— 15 μH	1
	0— 80 „	5
	0—350 „	20
$2 \times 10 \text{ mH}$	0— 0.15 mH	1
	0— 0.8 „	5
	0— 3.5 „	20

Measurement of Dielectric Losses in Capacitors.

Due to the relatively high measuring frequency (100 kc/s) the Deviation Bridge Type 1506 is excellently suited for checking of loss factors of capacitors.

However, for very exact measurements the impedance of the “Standard” capacitor and the impedance of the capacitor to be tested should be equal. By parallelling the “Standard” capacitor with a small variable capacitor (the $\tan \delta$ of which should be 0) this condition can be satisfied.

The Bridge should then first be switched to impedance measurements, and the meter deflection adjusted to zero by means of the variable “standard” capacitor. When switched to phase angle measurement, the deviation of $\tan \delta$ from the standard capacitor is read off the scale.

If the loss in the standard is approx. zero (or very small compared to the loss in the capacitor being tested) the measured $\tan \delta$ is equal to the $\tan \delta$ of the capacitor under test.

Adjustment of Inductances.

An R. F.-coil is characterised by its inductance value, L , and quality factor

$$Q = \frac{1}{\tan \delta}$$

When manufacturing coils, the usual procedure is to design a "Standard", and the coils produced by the manufacturing process shall then equal this "Standard" to within certain limits.

A convenient method of checking and adjusting the coils, is by employing a Deviation Bridge Type 1506.

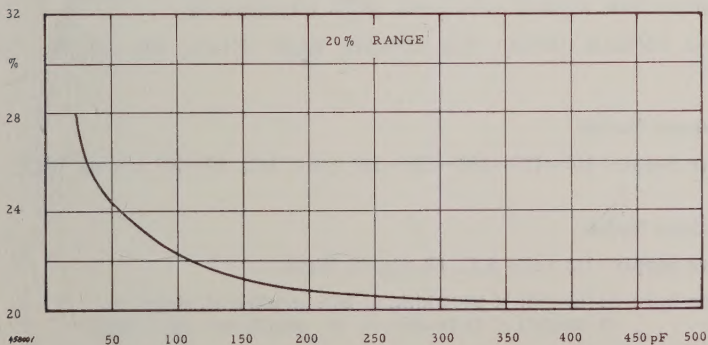
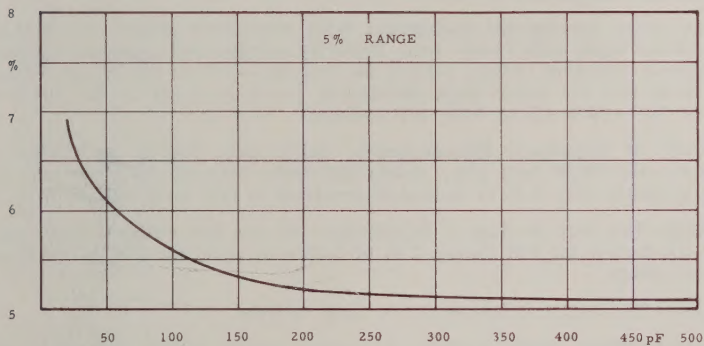
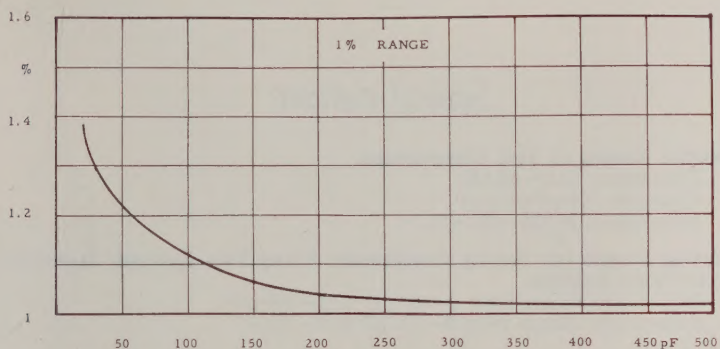
The "Standard" coil should then be connected to the "Standard" terminals, and the coil to be checked to the "Unknown" terminals.

With the switch on "Impedance" the inductance is adjusted to give zero reading. The switch is then set to "Phase Angle" and the Q of the coil adjusted to show 0 phase angle deviation.

Usually L and Q are, to a certain degree, dependent upon each other and it is therefore advisable to repeat the procedure when exact measurements are wanted.

Correction Curves for Reference Point Adjustment.

Type 1506.



Specification.

Measuring Ranges of Test Components:

Resistance: 10 Ω —50 k Ω .

Capitance: 20 pF—0.1 μ F.

Inductance: 20 μ H—20 mH.

Measuring Ranges for Testing Components, Using Two External Standards: Permits Direct Reading:

Inductance Range from 0—0.3 μ H to 0—3.5 mH.

Capacitance Range from 0—1.5 pF to 0—35 nF.

Measuring Frequency: 100 k/cs.

Meter: Large moving-coil instrument with removable scales (see figure). Illuminated scale with centre zero. Perfectly safeguarded against overloads. Impedance deviation ranges: —1.5 % to +1.5 %, —7 % to +8 % and —25 % to +35 % and for phase angle deviations: $(-1.5 \text{ to } +1.5) \times 10^{-2}$, $(-7 \text{ to } +7) \times 10^{-2}$ and $(-25 \text{ to } +25) 10^{-2}$ radians.

Accuracy of Impedance Measurements: Better than 0.03 % for deviations close to zero. With zero phase angle difference between standard and unknown: Better than 3 % of indicated deviation at full scale deflection.

Stability: The zero reading is independent of the line voltage. Deflections from the zero point will change 3 % of indicated value for a 10 % variation of line voltage.

AC-Hum: The bridge is insensitive to hum voltages.

Impedance-Phase Angle Switch: A special micro switch permits rapid switching from impedance to phase angle measurements.

Tubes: 2 $\times$ 6AU6 (EF94), 6U6 (ECC91), 6AQ5 (EL90), 6X4 (EZ90), OA2 (150C2).

European Model:

Power Supply: 115—127—150—220—240 volts. A.C., 40—400 c/s, 40 Watts.

American Model:

Power Supply: 115 volts A.C., 60 c/s, 40 Watts.

Dimensions: 33 (height) $\times$ 28 (width) $\times$ 20.5 (depth excl. dials) cm.
13 (height) $\times$ 11 (width) $\times$ 8 (depth excl. dials) inch.

Weight: 10 kg (22 lbs.)

